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Remote Access of an Autonomous Seed Sowing Robot in a Learning Factory

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Abstract

The supervision of food production systems is instrumental in the advancement of food security. Remote access and control provides unique capabilities to the supervision and operation of such systems, as well as interesting opportunities for students to access learning factory facilities remotely. Thus, the AllFactory at the University of Alberta provides a unique environment that allows for testing of highly robotized food production lines. This paper proposes the use of digital twin models to enable remote access to learning factory's systems and combines distributed sensors and computer vision to visualize the systems' operational status and motions while also providing a remote learning environment. In this study, a digital twin of a robotic seed sowing system, consisting of a Dobot M1 robotic arms is developed and tested. The robot system aims to pick crop seeds using pneumatic actuators and finally place them correctly in rockwool, while several cameras monitor seed and plant growth. The development of this tool hopes to support the continuous use of learning factories even in complicated situations.

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Keywords: digital twin, production line; cloud computing; learning factories; internet of things; autonomous systems.

1. Introduction

With the still on-going Covid-19 pandemic, most university courses have been profoundly affected during the past two years. With the emergency transition to online learning, delivering hands-on and interactive practical sessions is a challenging task. Learning factories have not been any different and a clear disruption to its use as a learning and research tool has occurred. To replicate the practical experience and physical instructional support using decentralized and remote environments is often impossible without extensive efforts to alter the teaching methods. For example, delivery of practical sessions have been adapted by the ECUST in Shanghai to be suitable for remote teaching as 'simulations', 'virtual experiments', or 'remote control experiments' on topics such as chemistry, physics, computer networking, or electrical engineering, among others [1]. Thus, allowing remote access to laboratories during this period has been key for students to achieve practical competences in their studies.

With novel automation technologies and increased web speed, remote access laboratories have spreaded out within the science and engineering communities [2]. These types of laboratories offer a wide range of benefits including overcoming time and space constraints, easing users' access to machinery and instrumentation increasing utilization, and enabling distance education through practical sessions [3].

Considering the practicability, focusing on novel technologies, and their relative recency, enabling remote access to learning factories could have been implemented following remote access laboratories frameworks [4].

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This paper proposes remote access of learning factory's devices following a remote access control followed by a digital twin implementation to handle most shortcomings of current remote access laboratories. This proposed approach is implemented in a robotic seed sowing robot within the AllFactory at the University of Alberta, Canada.

2. Remote access system

In this study, a method is developed for which highly automated food production systems can be supervised remotely while also fostering a learning environment, without compromising cyber-security. To achieve this, a remote access control system to a digital twin model is developed for an autonomous seed sowing robot located within the AllFactory [5]. The access control system consists of four layers which are described in Fig. 1. The first layer is a virtual private network (VPN) which is used to authenticate the user as a legitimate University of Alberta student while also encrypting communications.

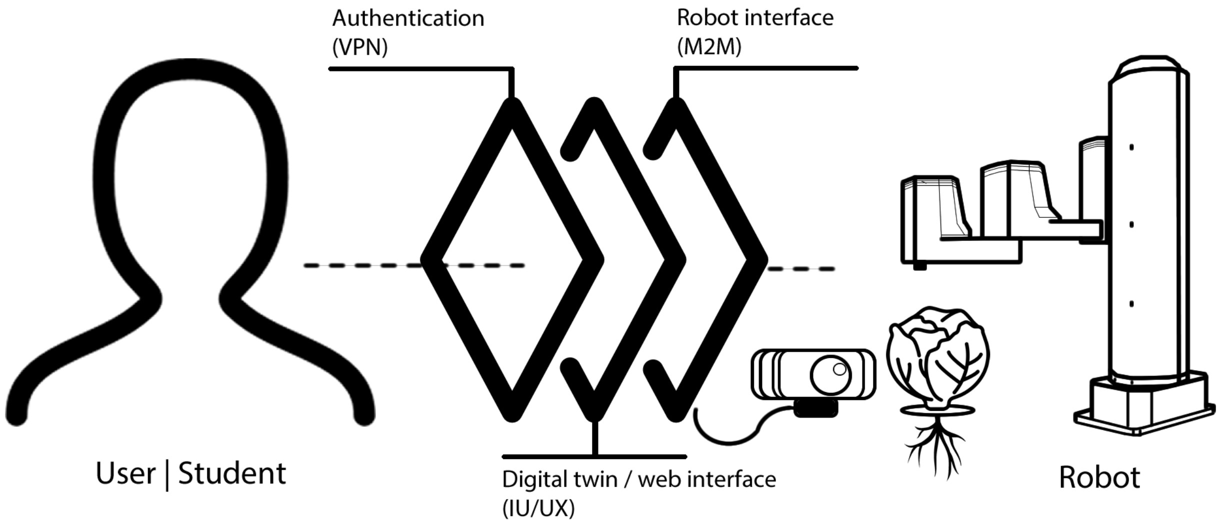

Fig. 1. The proposed remote access control system and its layers.

The second layer consists of a web user interface (HTML5) that connects the users/students to the digital model of the digital twin, as well as providing the information obtained through sensors at the learning factory. The digital twin is an enabling technology that allows for seamless integration of both cyber and physical spaces [6]. This allows for a single, highly trained individual to have control over several processes distributed along several sites only by having access to an internet-enabled computer. For example, for this study, users have access to a streaming live video of the robot while simultaneously visualizing a 3-dimensional model and other telemetry real-time data of the robot that is being controlled. This model is directly obtained from the digital twin and is completely synchronous to the physical robot in the learning factory.

The third layer is a communications layer between the web user interface and the physical system that is used to interpret user input and properly communicate it to the robotic system. User input can be directly introduced through the web interface as a script or an array of coordinates that the user wants the robot to move to.

The fourth and final layer is the physical system itself, where the food production actually takes place. This framework can be implemented for any cyber physical system that requires remote control and specialized supervision, like other highly specialized industrial or productive equipment.

2.1. Authentication layer

Since this framework is thought to be a universal guideline for remote connectivity to digital twin systems, authentication and security make up the first layer of the system architecture. The University's infrastructure proved to be invaluable in the development of the authentication methodology. The access to the digital twin web interface is granted by connecting to a virtual private network (VPN) by using the engineering department credentials [7]. This ensures that communication between the user and the system is encrypted and thus reduces the exposure to potential attacks. Also, it ensures compliance with data protection policies as data is shared between the user and the learning factory server.

Also, the student's identification number is required to authenticate into the system. This means that only enrolled students can access the cyber and physical spaces where the digital twin is located. Remote students only require their credentials and the VPN client software to gain access to the digital section of the learning factory. Furthermore, the login record and other forms of usage tracking can help monitor user interaction with the platform [8]. Once a secure connection is established between the user and the private network, full access to the digital twin system can be gained by following an IPv4 address for the webserver.

2.2. Web interface for the digital twin instance

A small web server running the digital twin instance is locally hosted and serves as a user interface (UI) between the user and the machine to machine (M2M) communications layer [9]. A web UI allows for dynamic use of the platform since it can be accessed by any device with a web browser, mobile or desktop. HTML5 proved to be instrumental to building the platform [10], since the video stream uses OGG codec that can be displayed natively and fluidly [11]. Neat and uninterrupted video is essential for a positive user experience. An array of sensors like atmospheric CO_2 and color sensors can be used to monitor plant growth [12-13]. A representational state transfer application programming interface is used to receive user input and send it to the communications layer. Using *get* and *post* HTTP requests, data and instructions can be exchanged between the digital twin and the system user.

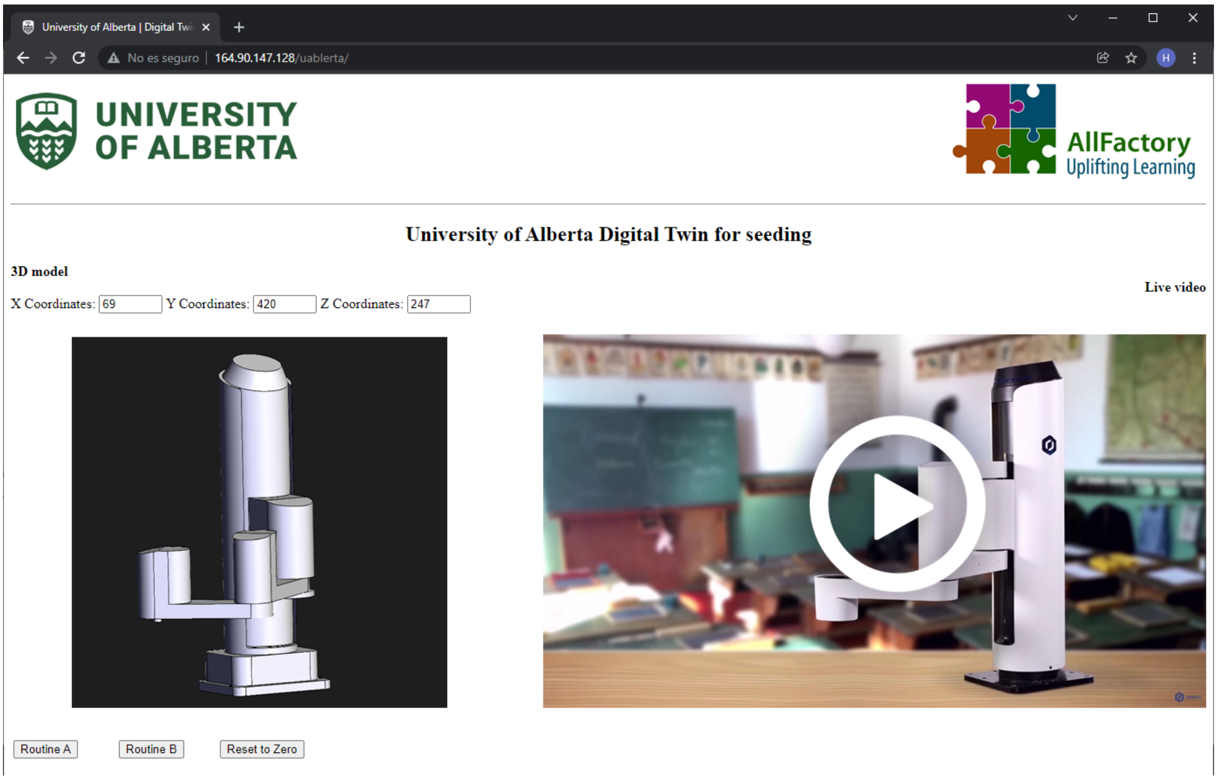

Fig. 2. Screenshot of the web-based user interface.

2.3. Machine to machine (M2M) communications layer

In order to provide a seamless interaction between the cyberspace and “the real world” - often referred to as meatspace - a communications layer that allows for apparently instantaneous exchange of data is necessary. DOBOT is a Chinese hardware manufacturer that specializes in light weight robotic arms. Their DOBOT M1 model was deemed to be very well suited for the purposes of this study due to their native code integration and open-source capabilities.

2.4. Hardware

The base of the robotic system is the DOBOT M1 robotic arm. For the purpose of this study, the M1 robot is retrofitted with a compressed air gripper and actuator. The gripper is designed to use compressed air to hold seeds individually and release them in small pockets within rockwool seed beds. These beds are responsible for the initial seeding and growth for the future plants that are used downstream, and represent the first step within the AllFactory.

3. Conclusions and discussion

Considering the recent emergency transition to online learning and remote conditions of most educational institutions, learning factories have seen their teaching and research activities affected. With traditional face-to-face student engagement out of the picture for quite some time, the educational use of learning factories has been challenged. Expanding current frameworks of remote access laboratories, this paper explores remote access control capabilities along with digital twin technologies to enable student use of learning factories remotely. The remote access system is created as a four-layered platform: starting with an authentication layer that ensures cybersecurity and encryption of any transferred data; a web-based layer that holds the user interface in which students can view and interact with the current machinery at the learning factory; a machine to machine layer that ensures constant communication between physical elements, as well as the user via scripts; and the physical layer or the learning factory itself. For this study, an autonomous seed sowing robot from the AllFactory at the University of Alberta is used as a proof of concept.

Although the circumstances may have pushed towards different teaching methods, enabling remote access and use of learning factories may be of interest anyway. Having such systems and platforms can ease the industrial use of the learning factory for training purposes, it can support collaborative use and development of learning factories between multiple institutions (increasing their efficiency and impact), as well as helping as a demonstrative marketing tool. Overall, learning factories have a lot to gain and to give if a safe remote access is implemented.

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